AD-A166 203 PULSED CHEMICAL LASER TECHNOLOGY DEVELOPMENT TEST PLAN 1/1
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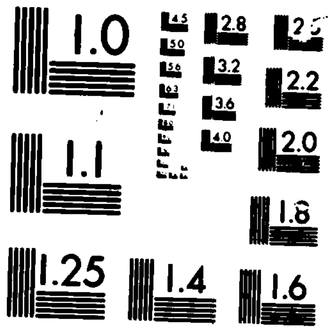

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PULSED CHEMICAL LASER TECHNOLOGY DEPARTMENT TEST PLAN

SINGLE PULSE DIAGNOSTIC TESTING

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AD-A166 203

PULSED CHEMICAL LASER TECHNOLOGY DEVELOPMENT

TEST PLAN

SINGLE PULSE DIAGNOSTIC TESTING

Contract No. DAAHC1-83-C-0282

Prepared For

Department of the Army

U.S. Army Missile Command

Redstone Arsenal, Alabama

Prepared By

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Everett, Mass.

Pulsed Chemical Laser Technology Development Program Test Plan

Single Pulse Diagnostic Testing

1.0 INTRODUCTION

Single pulse DF and DF/CO_2 transfer laser testing will be conducted to expand the data base for verification and extension of performance scaling relations. Scaling relations are currently based on the analytical effort completed under Task I and the caparison of this analysis with available data.

Tests will explore the effects on performance of gas composition with constituents including F_2, D_2, O_2, HF, NF_3, He, N_2, and CO_2 at both DF and CO_2 wavelengths. Tests will explore the nature of the gas medium in terms of F atom initiation level and gain, the nature of the initiating electron beam source in terms of energy deposition level and uniformity and pulse length, and laser yield in terms of total energy, pulse shape and time resolved spectra. The system will operate at pressures ranging from 200 to 760 torr.

The test plan is preceeded by a detailed schedule for implementation of special diagnostics and repetitive pulse power as well as single pulse laser testing. This illustrates the timing of applications of special diagnostics and the availability of time for single pulse testing. Coordination of this with implementation of repetitive pulse power is crucial to the scheduled start of repetitive pulse laser testing in July 1984. Single pulse testing capabiliy will be retained throughout the repetitive pulse testing period. This will allow continued laser testing even in the event of temporary down time for the repetitive pulse power system.

The first two single-pulse test intervals (total two weeks) are viewed as system shakedown and have been described in a letter to MICOM (J.M./Walters) dated 3/1/83. These tests are included in this document for completeness.

2.0 OVERALL EXPERIMENTAL PROGRAM

All elements of laboratory effort through to the start of repetitive pulse testing are listed in schedules of Table I (3 parts), Table II and Table III. Final system shakedown of all new gas handling will be completed 2/24/84. On-line fluorine system shakedown and laser optics installation will be completed 3/2/84. Diagnostics for F-atom production measurements will be installed in the same period.

Laser performance shakedown will be conducted during the week of 3/5 - 3/9. This test will repeat a previous run with a composition of 20 percent F_2, 6 percent D_2, 1 percent O_2. 73 percent He. Calorimetry and laser pulse shape data will be compared with earlier studies to verify the workability of the system after the extensive modifications completed under the current contract. The operational capability of the F-atom formation diagnostics will also be tested.

An improved E-beam cathode will be installed and tested during the week 3/12 - 3/16. This cathode as described in CDR will substantially improve efficiency of conveyance of electrons to the cavity. It will thereby improve electrical efficiency and reduce the power demand on the power supply system.

Laser performance shakedown with the new cathode will be conducted during the week 3/19 - 3/23. In this period, the operation of the jet pumps will be tested in combination with laser testing at subatmospheric pressures.

The test period proper begins 3/26/84. A two-week test period is indicated. During this time, the laser spectrometer will be installed and time integrated spectral measurements will be conducted. The parallel development of time resolved spectral measurements is shown in Table I. After this two-week test period, additional E-beam performance testing will be conducted in the week 4/9 -4/13.

Implementation of the repetitive pulse power system is shown in the schedule of Table II. Much of the construction is done as modular subassemblies. Certain of the components may be installed in the facility without disrupting laser testing. The period between 4/9 and 5/4/84 is to provide for installation and testing which may be disruptive to laser performance testing. During this period, the facility is dedicated to this effort although diagnostics implementation continues.

Laser performance testing will be conducted during the weeks 5/7 - 5/11 and 5/14 - 5/18. During this time, the F-atom production and the time resolved laser spectral diagnostics will be operational and will be implemented. Time resolved laser spectral measurements require a multichannel data acquisition system which will be implemented as shown ion the schedule of Table I.

The above laser measurements will address DF performance. Conversion to DF/CO_2 operation will be conducted during the week 5/21 - 5/25. Performance measurements for DF/CO_2 transfer laser operation will be conducted during the weeks 5/28 - 6/1 and 6/4 - 6/8. This will complete single-pulse laser performance testing, and the system will be converted for repetitive pulse testing.

Implementation of time dependent gain measurements is scheduled for completion in the week 4/30 - 5/4; however, the tight schedule shows only tentative testing in this single-pulse test period. It may be necessary to postpone these measurements until the repetitive pulse test period. The single-pulse Marx bank driver will be available and operational during the repetitive pulse test period. This will allow operation in this mode, should there be down time for the repetitive pulse power system.

Additional studies in PCL development, which are supported under IRAD funding are shown in Table III for completeness. These efforts address E-beam foil survival under PCL stress and thermal environmental conditions and the development of novel mechanical valving for DF laser applications. Their development does not impinge on single-pulse laser testing.

3.0 SINGLE PULSE DIAGNOSTICS TEST PLAN

3.1 DF Laser Performance Test Plan

Shakedown testing during the week 3/5 - 3/9 (Table I) will duplicate operating conditions of a previous test series. This will reestablish operational capability after the extensive changes which have been made to the system under the current contract. This device baseline operation at 20 percent F_2, 6 percent D_2, 1 percent O_2, 73 percent He yielded

25 J/(ℓ atm (DF) with outcoupling of 63 percent and a 100 cm gain length. Electron energy deposition was computed to be 4.1 J/ℓ. Scaling relations developed by Mirels predicted an initial F-atom production level of F/F_2 = 0.13 percent for this laser energy yield. Modeling by Physical Sciences Inc. predicted these same initiation/yield conditions when results were scaled on the basis of past comparisons with experiments. On this basis, the code was "anchored" to present device performance, and modeling tests were conducted. The principal guides to development of a test matrix are system capabilities, and the pursuit of operating conditions and performance which are predicted by the PSI modeling effort to be advantageous to Army applications.

Modeling results predict an improvement in baseline yield of 30 percent by decreasing the outcoupled fraction from 63 percent to 40 percent. Implementation of this change is not practical in the present experiment due to added laser optics alignment difficulties. It does, however, indicate a potential improvement in larger devices since the same benefit is obtained by increasing the gain length.

Laser performance with increasing initiation strength, i.e., electron energy deposition level, has been explored with this device for atmosphere pressure operation and with Helium diluent. These results were reported in the September 29th review and will not be duplicated in this test series. The

primary conclusion from these tests was that the laser yield increased with E-beam initiation strenth so long as the E-beam pulse length did not strongly overlap the laser pulse. On this basis, the current system will incorporate an new cathode design which will double energy delivered to the gas during a 0.5 μsec pulse. After implementation, the laser energy yield will be measured during the week 3/19 - 3/23 under conditions otherwise identical to the baseline case described above. With electron beam characterization for both E-gun configurations, comparison of laser energy yield will provide a determination of the relationship between yield and initiation strength. F-atom production diagnostics will be implemented during these tests to provide a direct determination of initiation strengths.

Since the F-atom production diagnostics measure HF concentration, the above tests will include a comparison of performance with minimum attainable HF concentration with that which is present in delivered Fluorine cylinders without cleanup. The tests of 3/19 - 3/23 will also examine laser yield as a function of cavity pressure. This will provide the first testing of jet pump operation in combination with laser performance testing.

The above tests are shown in the Test Matrix of Table IV. These will complete shakedown and allow commencement of the test series proper. Test elements listed in Table IV refer to laser performance measurements only. Electron beam testing and other testing is shown in Tables I, II, and III.

The effects of Helium diluent removal will be examined during the test period 3/26 - 4/6. This is of primary importance to Army applications where chemical pumping of all laser exhaust is required. It is also of interest in systems studies since modeling results predict no degradation in DF laser yield with He diluent removal. These predictions are based on constant concentration of stabilizing O_2 at 0.01 atm. It is anticipated that O_2 concentration will necessarily increase with decreasing He in the experiment to maintain stability. Since the requirements for minimum O_2 must be determined experimentally, we anticipate two weeks will be required for these tests. One notes from previously reported modeling results that O_2 has a dramatic negative impact on laser yield, hence its minimum stable concentration must be established for each level of He removal. The laser spectrometer will be installed during this test period in a configuration which will allow time integrated measurements.

Production of gaseous F_2 from solids by current techniques produces NF_3 as a by-product. The ratio of NF_3 to F_2 is to date 6/5, however, current studies indicate that this may ultimately be reduced to nearly zero. It is important to know the overall impact of NF_3 presence on laser performance. It acts as a chain reaction terminator on the negative side but it acts as a stabilizer and as a source of F-atoms in E-beam pumped systems on the positive side. Modeling studies predict a degradation in laser yield of a factor of 0.77 when 0.24 atm of NF_3 is added to a diluent free mix of

0.2 atm F_2, 0.06 atm D_2 0.01 atm O_2. This compares with a degradation of 0.94 with equivalent N_2 dilution and no degradation with equivalent He dilution. These results are based on constant O_2 concentration and do not address the added F-atom yield from NF_3 or N_2. Test series 5/7 - 5/18/84 will address laser performance with NF_3 dilution from zero to 0.24 atm and with N_2 dilution from zero to 0.73 atm. Nitrogen dilution is of interest since further reduction in NF_3 yield from solids is attended by an increase in N_2 yield. The test matrix thus far addresses all the major issues associated with laser mixtures appropriate to Army applications. It is also of interest to explore other diluents such as SF_6 and Ar. These have not been included due to the tight test schedule. They will, however, be addressed i~~o~~n the repetitive pulsed test period. Gain measurements diagnostics are scheduled to be installed during this period. Implementation will depend upon system availability in view of the competing scheduling of other diagnostics. If implementation is not practical here, it will be postponed to the repetitive pulse test period.

If from NF_4BF_4 TRUE. If from $NF_4 \rightarrow NF_3 + F_2$, NO!

NOT CHEM PUMPABLE

3.2 DF/CO_2 Transfer Laser Test Plan

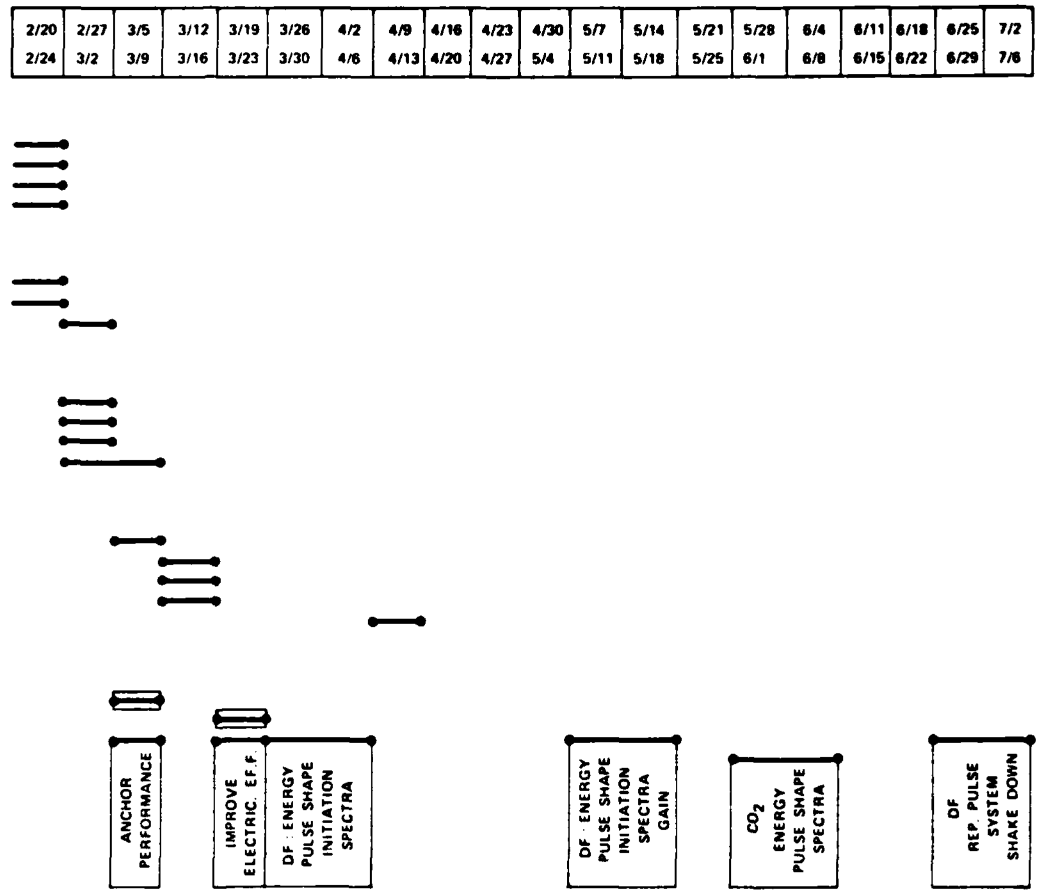
Laser calorimetry and medium probing techniques must be changed for DF/CO_2 performance studies. The calorimeter will be placed inside the mirror box and medium probing will be done through small ZnSe windows. Spectral measurements will require a different grating in the spectrometer.

After modifications, DF/CO_2 transfer operation will be studied in the test period 5/28 - 6/8/84. DF/CO_2 transfer laser performance studies will begin with no diluent and explore the dependance of laser yield on CO_2 concentration. Modeling predicts optimum performance near $CO_2:F_2 \sim 1:2$ whereas Aerospace experiments were conducted with high ratios of $CO_2:F_2$. Efficient laser performance at low $CO_2:F_2$ ratios would have a favorable impact on system weight and size. After establishing optimum CO_2 concentration, the effect of NF_3 diluent will be explored. If one neglects absorption, modeling studies predict no degradation in energy yield with NF_3 addition. However, absorption by NF_3 may be an issue and must therefore be resolved.

4.0 SUMMARY

The test plan addresses all the major issues relevant to Army applications. The test laser is a flowing gas laser. It is currently configured for repetitive pulse operation with the exception of a pulse power system which will be incorporated in June, 1984. Since laser gas handling is nearly the same for single and for repetitive pulse operation, it is much more efficient to broaden the test matrix in the repetitive pulse mode. For example, laser yield vs D_2 concentration may be explored in a single run with a large number of data points simply by reducing D_2 flow rate continuously with time through the run in a known way. Dependance on concentration of other species may be explored similarly.

TABLE I: TEST PLAN TASK III - SINGLE PULSE TESTING



A   GAS HANDLING
A1 TEST JET PUMP WITH CAVITY FLOW
A2 INSTALL SINGLE PULSE FLUIDIC VALVE DRIVE
A3 TEST FLUIDICS. p_c - 1.0 ATM
A4 TEST FULL FLOW p_c - 1.0 ATM, 0.5 ATM

B   FLUORINE GAS HANDLING
B1 INSTALL F_2 SUPPLY GAS CLEANUP
B2 INSTALL HF.HCl PLUMBING
B3 SHAKE DOWN F_2 GAS HANDLING

C   MAIN LASER OPTICS
C1 INSTALL LASER OPTICS AND CALORIMETER
C2 INSTALL LASER PULSE SHAPE DETECTOR
C3 SHAKE DOWN CALORIMETER DIAGNOSTICS
C4 SHAKE DOWN LASER ALIGNMENT OPTICS

D   SINGLE PULSE ELECTRON BEAM
D1 PUT CARBON FELT ON NEW CATHODE
D2 TEST TRANSMISSION OF OLD CATHODE, 1/2-IN FOIL BAR SPACING
D3 INSTALL NEW CATHODE
D4 TEST NEW CATHODE TRANSMISSION, 1/2-IN FOIL BAR SPACING
D5 TEST NEW CATHODE, FOIL BARS REMOVED

E   LASER PERFORMANCE MEASUREMENTS
E1 TEST DF LASER 1.0 ATM 20 F_2, 6 D_2, 1 O_2, 73 He
E2 TEST DF LASER 0.5 ATM, 1.0 ATM, 20 F_2, 6 D_2, 1 O_2 73 He
E3 DF LASER PERFORMANCE MEASUREMENTS, COMPOSITE
E4 CO_2 LASER PERFORMANCE MEASUREMENTS

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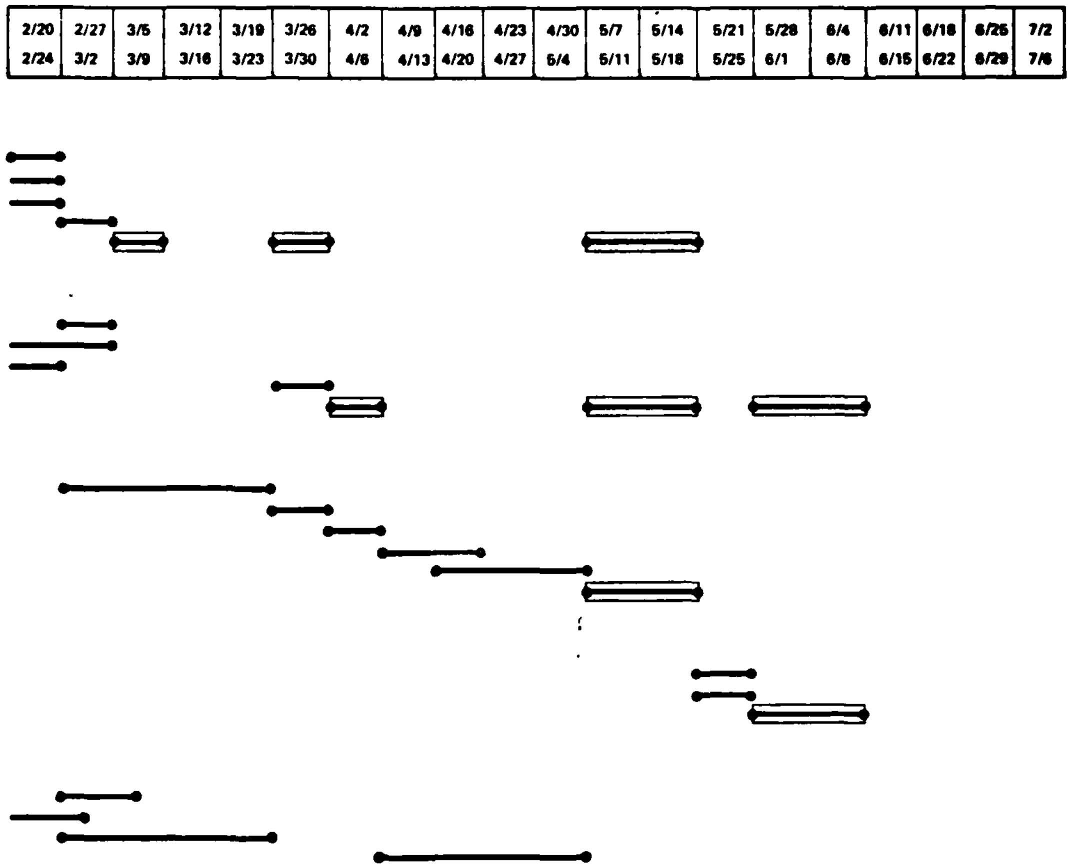
TABLE I: TEST PLAN: TASK III - SINGLE PULSE TESTING (Continued)



F FLUORINE ATOM PRODUCTION MEASUREMENTS
F1 FABRICATE F-ATOM REFERENCE AND TEST LEGS
F2 SHAKE DOWN LUMONICS DF LASER
F3 INSTALL F-ATOM CONVEYANCE OPTICS
F4 SHAKE DOWN F-ATOM DETECTORS
F5 MEASURE F-ATOM FORMATION

G TIME INTEGRATED LASER SPECTRAL MEASUREMENTS, DF
G1 INSTALL SPECTROMETER
G2 FABRICATE FILM HOLDER
G3 INSTALL FLASH LAMP
G4 IMPLEMENT LASER/SPECTROMETER ALIGNMENT
G5 MEASURE LASER $\int$ DF (λ, t) dt

H TIME RESOLVED LASER SPECTRAL MEASUREMENTS, DF
H1 OBTAIN DF (λ, t), CO_2 (λ, t) DETECTORS (10)
H2 INSTALL ONE COMPLETE DF (λ, t) DATA CHANNEL
H3 SHAKE DOWN ONE DF (λ, t) CHANNEL
H4 INSTALL DF (λ, t) DETECTOR ARRAY
H5 INTEGRATE DF (λ, t) WITH DATA ACQUISITION
H6 MEASURE DF (λ, t) - TIME RESOLVED SPECTRA

I TIME RESOLVED LASER SPECTRAL MEASUREMENTS, CO_2
I1 MODIFY CALORIMETER AND WINDOW FOR CO_2 (λ, t)
I2 MODIFY SPECTROMETER FOR CO_2 (λ, t)
I3 MEASURE CO_2 (λ, t) - TIME RESOLVED SPECTRA

J DATA ACQUISITION SYSTEM
J1 IMPLEMENT 2-CHANNEL A/D DATA ACQUISITION
J2 FINALIZE SELECTION OF DATA ACQUISITION SYSTEM
J3 OBTAIN DATA ACQUISITION SYSTEM
J4 IMPLEMENT DATA ACQUISITION SYSTEM

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TABLE I: TEST PLAN: TASK III - SINGLE PULSE TESTING (Continued)

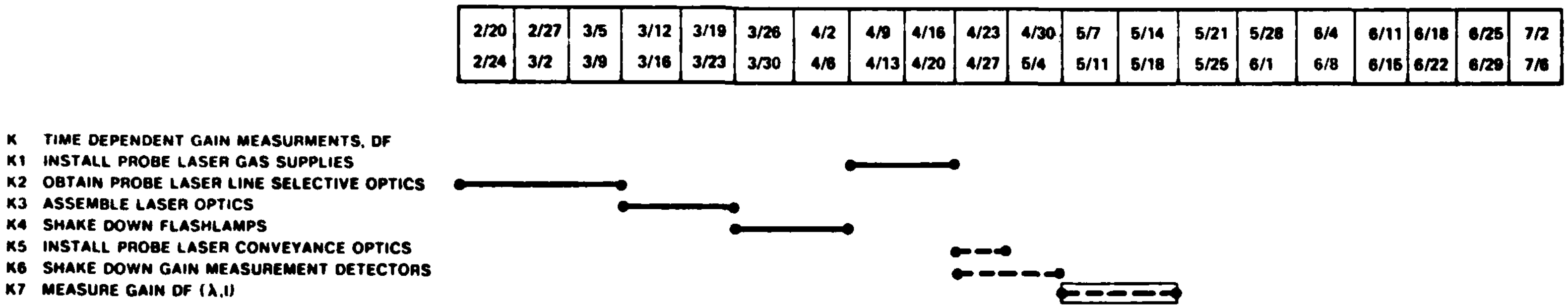

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TABLE II: TEST PLAN: TASK III - REPETITIVELY PULSED TESTING

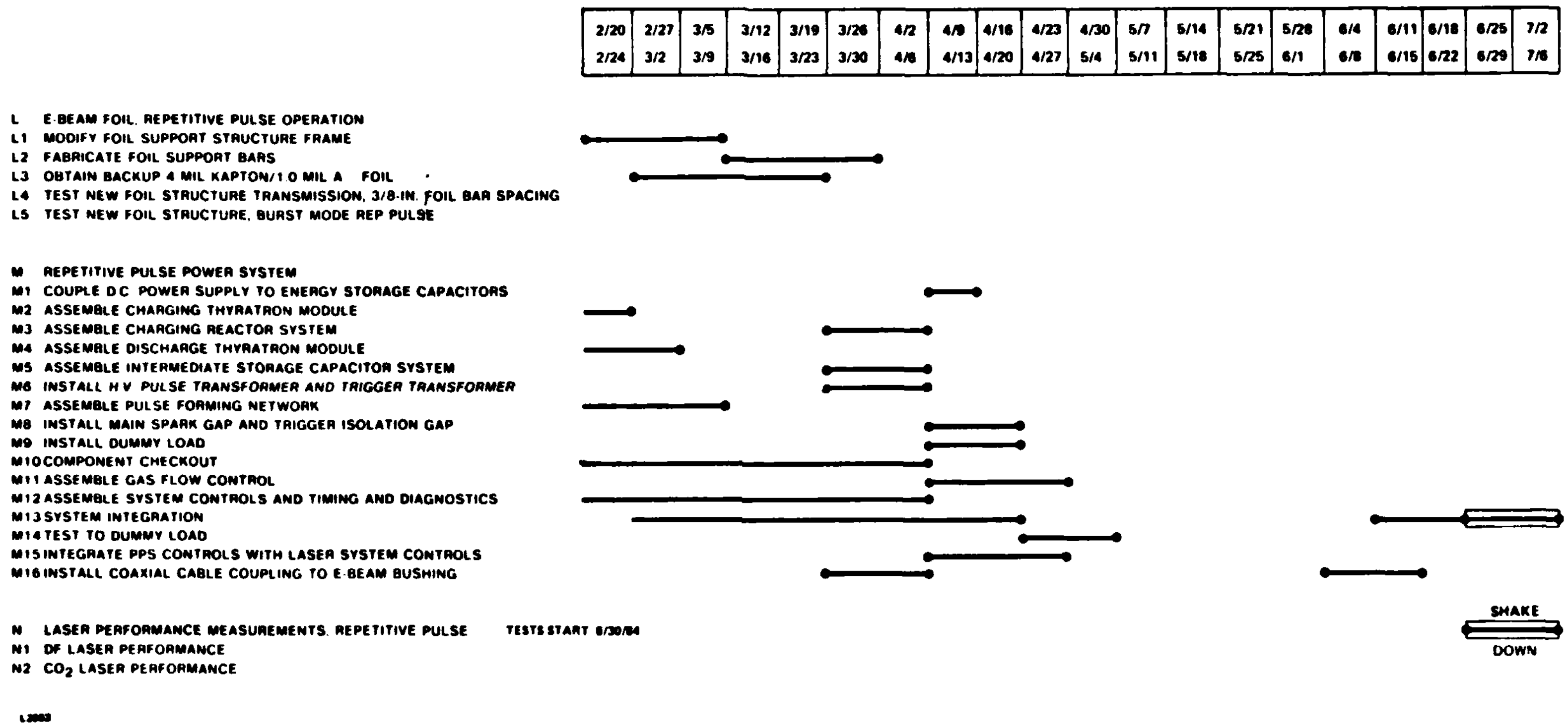

TABLE III: TEST PLAN: AERL-IRAD: REPETITIVELY PULSED TESTING

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TABLE IV. TASK III SINGLE PULSE TESTING – TEST MATRIX

SERIES	DESCRIPTION / PARAMETER	F_2 % OR ATM.	D_2 %	O_2 %	DILUENT %	HF %	CO_2 %	PRESSURE TORR.	INITIATION STRENGTH COUL/CM^2
3/5–3/9	SHAKE DOWN SYSTEM IMPLEMENT F-ATOM DIAGNOSTICS	20	6	1	He 73	MIN. VS. SUPPLIED	0	760	1.5
3/19–3/23	SHAKE DOWN SYSTEM WITH CATHODE MODIFICATIONS	20	6	1	He 73	MIN.	0	200-760	1.5-3.0
3/26–4/6	LASER PARAMETRICS He REMOVAL IMPLEMENT TIME INTEGRATED SPECTRA	0.20	0.06	AS REQUIRED	He–0.73 –0.0	MIN.	0	210-760	3.0
5/7–5/18	LASER PARAMETRICS ALTERNATE DILUENTS IMPLEMENT TIME RESOLVED SPECTRA	0.20	0.06	AS REQUIRED	N_2–0.73 –0.00	MIN.	0	210-760	3.0
		0.20	0.06	AS REQUIRED	NF_3–0.24 –0.00	MIN.	0	210-400	3.0
5/28–6/8	LASER PARAMETRICS DF/CO_2	0.20	0.06	AS REQUIRED	0	MIN.	0–0.73	210-760	3.0
		0.20	0.06	AS REQUIRED	NF_3–0.24 –0.0	MIN.	NOM. 0.2	360-540	

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